Physics 325 Assignment 5
Due Tuesday 3/3/09

1. a) ^{196}Au can decay by β^-, β^+, and EC. Write out each of the decay modes, and find the Q values for each of the decay modes. Again, atomic masses are given in most Modern Physics books, or at http://www.nndc.bnl.gov/masses/mass.mas03 (this website has the most recent evaluation).

BONUS: check your answers using the Q-value calculator at
http://www.nndc.bnl.gov/qcalc/

b) For which of the decays in a) will the emitted neutrinos have a range of possible energies? For which of the decays will the neutrinos have a single energy? Explain briefly why.

2. a) Consider a free neutron at rest beta decaying to a proton, electron, and electron anti-neutrino. The Q value (energy released in the decay) is 0.782 MeV. Argue that in analyzing the decay the proton can be treated non-relativistically, but the electron and the neutrino generally should be treated relativistically.

b) Show that if the electron anti-neutrino is emitted with essentially zero energy that the kinetic energy of the proton is given by

$$K_p = \frac{Q^2 + 2m_e c^2 Q^2}{2m_p c^2}.$$

Hint: conserve momentum and energy. Since the proton is much more massive than the electron, you can assume that the proton's kinetic energy will be negligible (to the precision of this problem) even if its momentum is equal to that of the electron's.

c) Evaluate this equation numerically for the case of neutron decay. Was your assumption that the proton's kinetic energy is negligible correct?

3. Using Fig. 14.5, estimate the thickness of each of the following materials that's needed to attenuate a beam of 10 MeV photons by 99.9%. Densities of materials can be found in many sources (give your reference).
a) Pb
b) Fe
c) C
Note: carbon comes in many forms with different densities, ranging from graphite to diamond—and even more exotic forms. Say which form you're using (shielding gamma rays with diamond may be expensive, though!)